Fishery Data Series No. 98-35

Abundance and Composition of Arctic grayling in the Delta Clearwater River 1996 and 1997

William P. Ridder

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Alaska Department of Fish and Game

Division of Sport Fish

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
metric ton	mt
milliliter	ml
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
ounce	oz
pound	lb
quart	qt
yard	yd

Spell out acre and ton.

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s

Spell out year, month, and week.

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
id est (that is)	i.e.,
latitude or longitude	lat. or long.
monetary symbols (U.S.)	\$, ¢
months (tables and figures): first three letters	Jan,...,Dec
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	F, t, χ^2, etc.
confidence interval	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
standard length	SL
total length	TL
variance	Var

FISHERY DATA SERIES NO. 98-35

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by

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ABSTRACT

Mark-recapture experiments were conducted along 14 mi of the Delta Clearwater River over a two-week period in July 1996 and 1997 to estimate abundance and composition of Arctic grayling *Thymallus arcticus.* Hook and line were used to capture 916 fish in 1996 and 1,491 fish in 1997. Fish $\geq$ 150 mm FL were not recaptured in 1996, so that estimates of abundance were truncated to fish $\geq$ 240 mm FL. In 1997, estimated abundance of Arctic grayling $\geq$ 150 mm FL was 9,000 fish (SE = 1,100). Estimated abundance of fish $\geq$ 240 mm FL in 1996 and 1997 was 3,000 fish (SE = 370) and 7,400 fish (SE = 920), respectively. Quality sized and larger fish ($\geq$ 270 mm FL) predominated in 1997. Ages 5 and 6 fish comprised 48% (SE = 2%) of the 1996 population while ages 4 and 6 comprised 46% (SE = 2%) of the 1997 population.

Key words: Arctic grayling, *Thymallus arcticus,* abundance, age composition, size composition, Delta Clearwater River, Alaska.

INTRODUCTION

The Delta Clearwater River (DCR) is a 21 mi long spring-fed system located 110 mi southeast of Fairbanks and 14 mi northeast of Delta Junction in the middle Tanana River drainage (Figure 1). It is the largest and most accessible of a number of spring-fed systems entering the Tanana River from the south. These spring-fed systems provide quality summer feeding habitat for Arctic grayling *Thymallus arcticus* that neither spawn or overwinter there (Reed 1961, Tack 1980, Ridder 1991). In this regard, the river's Arctic grayling fishery is unique among the major road accessible fisheries in the drainage because it is a mixed stock fishery. Immigration to the DCR begins in April with juvenile fish, followed by adults, and lasts into June. Emigration begins in August and is complete by December.

Since 1953, the river has offered a small but productive and popular Arctic grayling fishery known for its high catch rates, large Arctic grayling, and pristine water quality. The fishery harvested predominantly adult fish of ages 5 and older and had historical harvests that ranked in the top five Arctic grayling fisheries in the drainage. Average annual harvests prior to 1987 exceeded 7,000 fish but have since fallen to 30 fish through 1997 (Table 1). A drainage wide decline in abundance indices led to restrictive regulations enacted in 1987 for the DCR and other drainage fisheries. Regulations included the imposition of a catch and release season until the first Saturday in June, a 305 mm minimum size limit, a no bait restriction, and 5 fish daily bag and possession limit (limits were 10 fish daily and 20 fish in possession prior to 1977 and 5 and 10, respectively, through 1986). Results from catch-age modeling of the fishery (see Clark and Ridder 1994) from 1977 to 1990 and this study led to further restrictions to the fishery. A two fish bag and possession limit was imposed in July of 1995 through 1996 and the fishery became catch and release in June of 1997.

Stock assessments on the DCR have historically been monitoring programs centered on creel surveys; age and length sampling in April, May, and July; and July relative abundance estimates (the catch rate from one downstream pass of an electrofishing boat; Peckham and Ridder 1979, Ridder 1985). While these assessments were capable of detecting population trends, they did not give estimates of abundance, recruitment, survival and exploitation.

Specific objectives in the Federal Aid Contract, projects F-10-12 and F-10-13, Jobs R-3-2(c) were to:

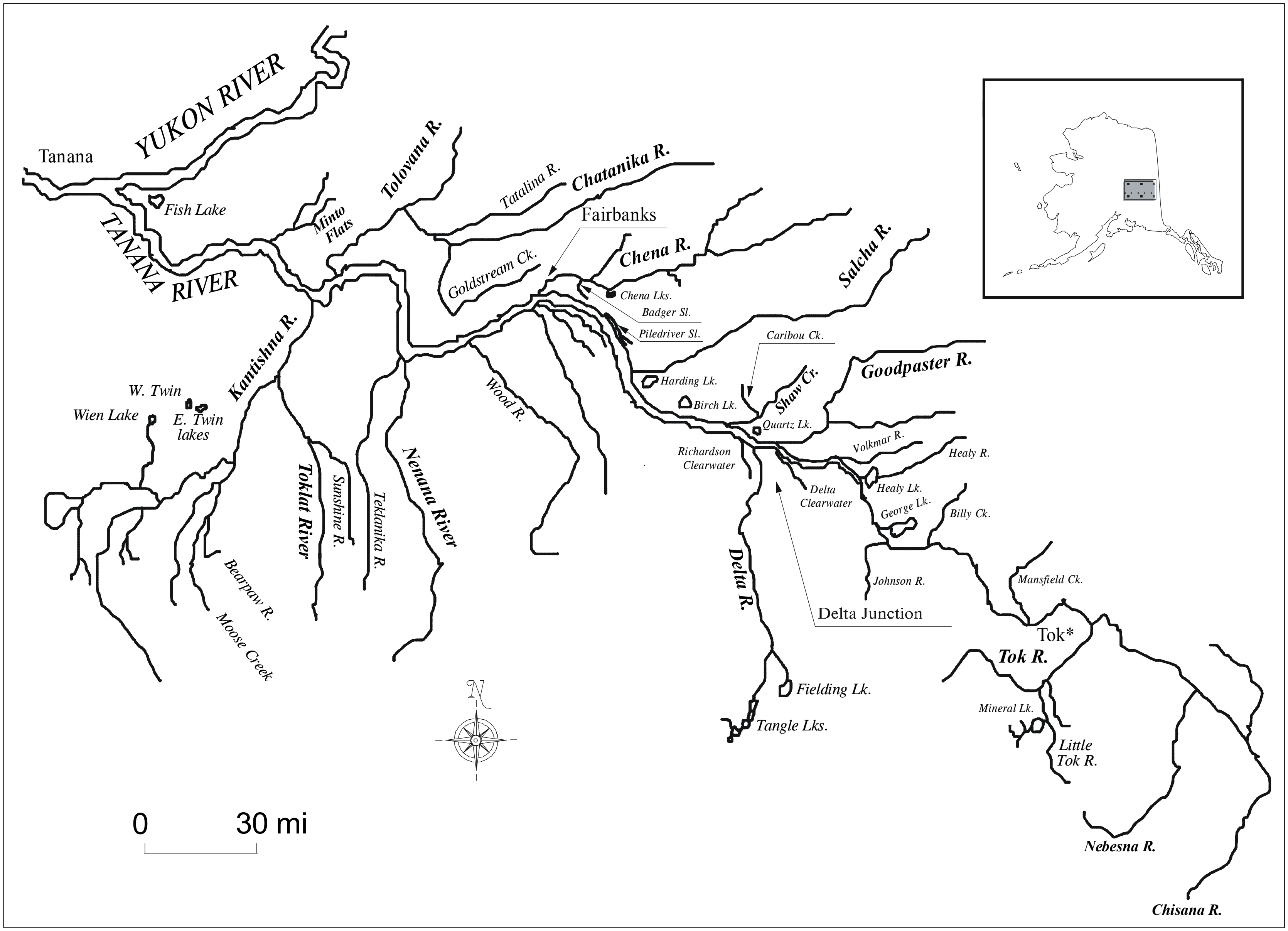

Figure 1.-The Tanana River drainage.

Table 1.-Estimates of harvest and effort in the fisheries of the Delta Clearwater River from the Statewide Harvest Survey, 1977-1997 (Mills 1978-1994; Howe et al. 1995-1998).

		Angler	Arctic grayling		Coho	
Year	Anglers[a]	Days[a]	Harvest	Catch	Harvest	Catch
1977	na[b]	6,881	6,118	na	31	na
1978	na	7,210	7,657	na	126	na
1979	na	8,398	6,492	na	0	na
1980	na	4,240	5,680	na	25	na
1981	na	4,673	7,362	na	45	na
1982	na	4,231	4,779	na	21	na
1983	na	5,867	6,546	na	63	na
1984	2,024	5,139	4,193	na	571	na
1985	2,947	8,722	5,809	na	722	na
1986	3,693	10,137	2,343	na	1,005	na
1987	3,068	5,397	2,005	na	1,068	na
1988	2,413	5,184	2,910	na	1,291	na
1989	2,845	5,368	3,016	na	1,049	na
1990	2,498	4,853	1,772	12,424	1,375	3,271
1991	3,171	5,594	2,165	7,998	1,721	4,382
1992	1,770	3,756	797	6,086	615	1,555
1993	1,491	4,909	437	5,712	48	1,695
1994	2,100	3,984	1,411	9,306	509	3,009
1995	2,927	6,261	926	5,974	391	5,195
1996	2,523	4,622	957	9,448	983	2,543
1997	1,866	2,925	30	4,665	866	4,174
Averages:						
1977-1997	2,524	5,636	3,495	7,702	596	3,228
1977-1986	2,888	6,550	5,698	na	261	na
1987-1996	2,481	4,993	1,640	8,135	905	3,093

[a] Anglers and angler-days represents effort on all species.

[b] na = not available.

1. estimate the abundance of Arctic grayling (≥ 150 mm FL) in the lower 17 mi of the Delta Clearwater River;
2. estimate the age composition of the Arctic grayling (≥ 150 mm FL) in the lower 17 mi of the Delta Clearwater River; and,
3. estimate the length composition of the Arctic grayling (≥ 150 mm FL) in the lower 17 mi of the Delta Clearwater River.

In addition, estimates of age and size composition of fish ≥ 270 mm FL and hook and line catch rates are given in the Appendix B to provide comparisons with published historical data from the Delta Clearwater River.

METHODS

Since Arctic grayling have historically been present up to mile 17 of the Sawmill Creek fork of the DCR (Figure 2), boat surveys of the upper river were conducted in 1996 and 1997 immediately prior to the experiment to set the upper boundary of the study area. (Few, if any, Arctic grayling inhabit the North Fork, personal observation.) In both years, no fish were observed above mile 15 and less than 10 fish were observed in mile 15 in 1996 and 30 fish in 1997. The upper boundary of the study area for both years was thus set at mile 14, the confluence of the two forks. The study area was divided into two sections at mile 8. Mile 8 is an approximate dividing line between gross differences in river morphology. Above this mile, the river is distinctly more shallow and narrow than the reach below. Mile 8 is also the location of the river's sole state campground and public boat launch. Creel surveys from 1976 through 1990 have also used the boat launch as a boundary in recording angler use/preference patterns.

Sampling was similar in both years and used hook and line gear to capture Arctic grayling during the last two weeks in July. Terminal tackle included flies, crappie jigs, and small spinners. Two person crews were positioned along the study reach at 2 mi intervals beginning at mile 14. Crews were made up of both volunteers and department personnel. They proceeded downstream fishing each pool and run in a systematic manner covering 0.5-1 mi in a day. More than one pass through some reaches was necessary in 1996 to meet sample goals. Captured fish were retained in an on-board live well and then deposited in seven holding pens that were positioned approximately every 2-mi beginning at mile 12 to the mouth. Individual fish were held in the pens from 2 to 4 days prior to sampling to prevent recaptures. Sampling began within two days of the end of each sample event at the upper most pen and proceeded downstream. All captured fish were sampled for age, length, old finclips and tags and then marked with a partial fin-clip prior to release (in 1997, left ventral for fish captured downstream of mile 8 and left pectoral for those captured above mile 8). Since there was a minimum of 2 days and a maximum of 7 days between passes and/or events for any one section, fish were assumed to disperse and lose any "gear shyness" between events.

All data pertaining to capture location, age, length, sex, tag numbers, tag colors, and losses (from previous studies), sampling mortality, recapture status, and finclips were recorded on mark sense forms. These were transformed into an electronic (ASCII) data file for analysis and archival (see listing of data files in Appendix A1).

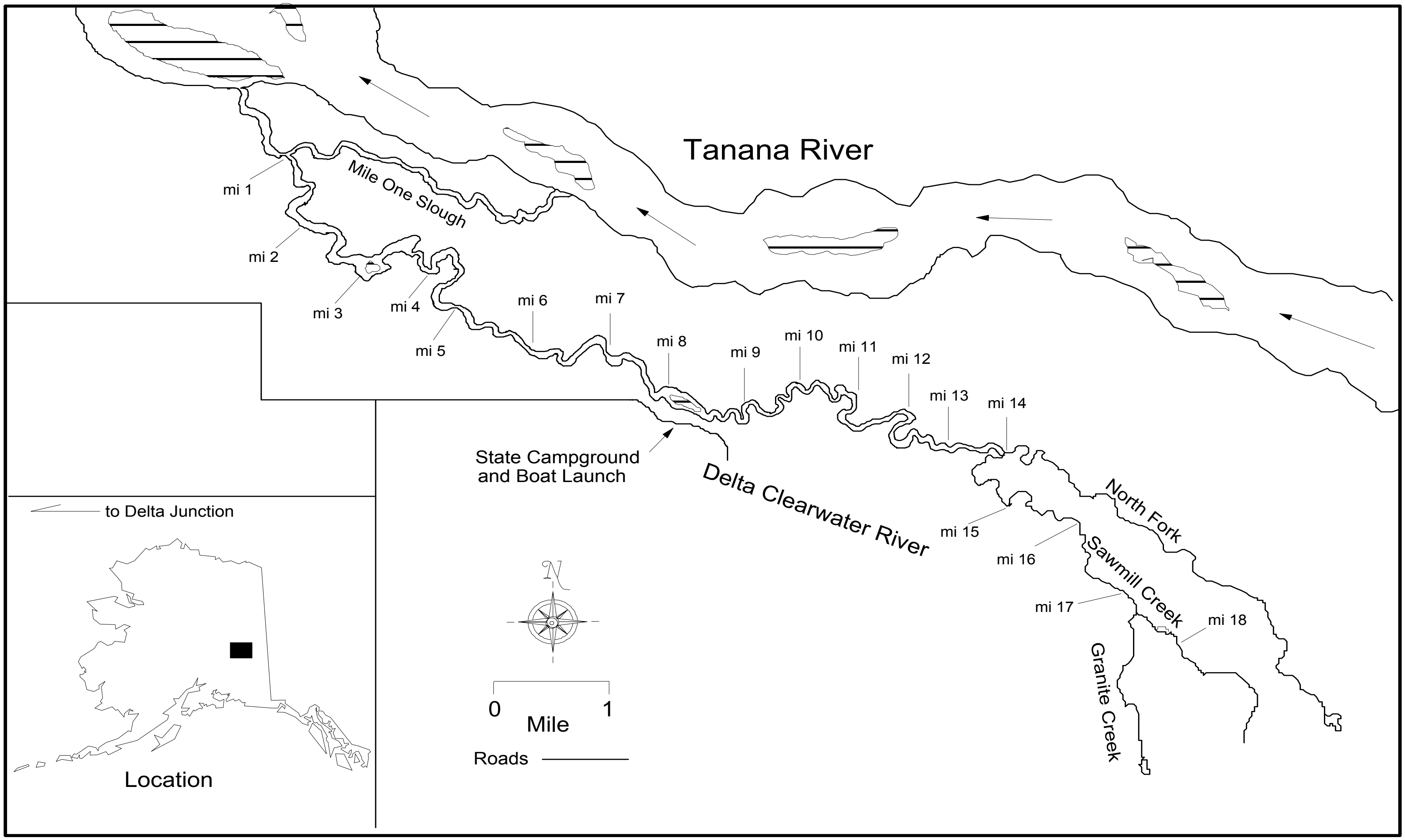

Figure 2.-The Delta Clearwater River.

Estimates were derived for three components of the population. The first component was determined from sampling results; estimates pertained to that segment of the population that was greater than or equal to the length of the smallest fish recaptured. The second component was necessary for comparisons to historical sample and harvest data and was for the population greater than or equal to 270 mm FL. This length is approximately equal to the minimum length for harvest in the fishery (305 mm TL) and approximates the adult component of the population (Clark 1992). The third component was for the population age 5 and older. This component was the target population of catch-age estimates (Clark and Ridder 1994) and was based on the age at full recruitment to the population and fishery.

ESTIMATION OF ABUNDANCE

Abundance of Arctic grayling ≥ 150 mm FL was estimated with the modified Petersen estimator of Bailey (1951, 1952). The assumptions necessary for accurate estimation of abundance in a closed population are (from Seber 1982):

1. the population is closed (no change in the number of Arctic grayling in the population during the estimation experiment);
2. all Arctic grayling have the same probability of capture in the first sample <u>or</u> in the second sample, <u>or</u> marked and unmarked Arctic grayling mix completely between the first and second samples;
3. marking of Arctic grayling does not affect their probability of capture in the second sample;
4. Arctic grayling do not lose their mark between sampling events; and,
5. all marked Arctic grayling are reported when recovered in the second sample.

Testing of Assumptions

Assumption 1 was implicitly assumed because of the size of the study area, the short duration of each survey (the last two weeks of July), and results from other studies. Tack (1973) found little movement of Arctic grayling during the mid-summer feeding period in a six month study of a 150 mi reach of the Goodpaster River. Ridder (*In prep* and unpublished data) found 37 of 39 Arctic grayling in a radio telemetry study to have emigrated to the DCR by 5 June and 38 of the 39 fish by 23 June. He did not detect movement out of the river until 6 August in 1995 and 15 August in 1996. Thus the large section of river and the time of year reduced the probability of significant numbers of fish entering or leaving the study area between sampling events. The short duration reduced the likelihood that mortality or recruitment due to growth would occur between sampling events.

Assumptions 4 and 5 were assumed to be valid because of the distinctive and permanent marking and rigorous examination of all captured fish. Assumptions 2 and 3 were tested directly in three ways. First, changes in capture probability may have occurred within a section of river. These potential changes were investigated by dividing each river section into two areas, above and below river mile 8. To determine if capture probability did change between areas, the recapture-to-catch ratios of each area were compared using a Pearson chi square contingency table. The two rows of the table were the different areas and the two columns of the table were the number of recaptures in the area and the number of unmarked fish examined during the second event in the same area. If the recapture-to-catch ratios were significantly different ($\alpha = 0.05$), the data were stratified into areas and separate abundance estimates calculated for each area. In 1997, differential marking of fish allowed greater ability to detect movements and capture probability differences between sections. For the 1997 data, tests for the consistency of the Petersen estimator were performed as described by Seber (1982, page 438).

Secondly, capture probability may differ by size of fish. Two Kolmogorov-Smirnov (KS) statistical tests were used to determine if capture probability differs by size of fish. The first KS test compared the length frequency distribution of recaptured Arctic grayling with those captured during the marking event. The second KS test compared the length frequency distribution of Arctic grayling captured during the marking event with those captured in the recapture event. The first KS test was used to determine if capture probability varied by size of fish. The second KS test was used to determine if age and size data needed to be corrected for changes in capture probability.

Calculation of Abundance

Estimated abundance was calculated from numbers of Arctic grayling marked, examined for marks, and recaptured (Bailey 1951; Seber 1982):

$$\hat{N} = \frac{M(C+1)}{R+1}, \tag{1}$$

where:

M = the number of Arctic grayling marked and released alive during the first sample;

C = the number of Arctic grayling examined for marks during the second sample;

R = the number of Arctic grayling recaptured during the second sample; and,

$\hat{N}$ = estimated abundance of Arctic grayling during the first sample.

Variance was estimated by (Seber 1982):

$$\hat{V}[\hat{N}] = \frac{M^2(C+1)(C-R)}{(R+1)^2(R+2)} \tag{2}$$

Bailey's (1951, 1952) modification was used instead of the more familiar modification by Chapman (1951) because of the sampling design used on each river section. Seber (1982) found that if the assumption of a random sample for the second sample was false and a systematic sample was taken, then the binomial model of Bailey (1951, 1952) is more appropriate. The binomial model will hold in this situation when:

1. there is uniform mixing of marked and unmarked fish; and,
2. all fish, whether marked or unmarked, have the same probability of capture.

The sample design used in each river section does not allow for thorough mixing of fish marked at the uppermost reaches with those marked in the downstream reaches, although local mixing of marked and unmarked fish probably occurs.

ESTIMATION OF AGE AND SIZE COMPOSITION

For aging, scales were taken from the area approximately six scale rows above the lateral line just posterior to the insertion of the dorsal fin (W. Ridder, Alaska Department of Fish and Game, Delta Junction, unpublished information on refinement of methods described by Brown 1943). Scales were processed by wiping slime and dirt off each scale and mounting on gummed cards in the field. The gum cards are used to make triacetate impressions of the scales (30 s at 137,895 kPa, at a temperature of 97ºC). Ages were determined by counts of annuli from the triacetate impressions magnified to 40X with a microfiche reader. Criteria for determining annuli were: 1) complete circuli cutting over incomplete circuli; 2) clear areas or irregularities in circuli along the anterior and posterior fields; and, 3) regions of closely spaced circuli followed by a region of widely spaced circuli (Kruse 1959). Age composition was described with proportions of the stock contained in each age class from 2 through 12 years (third through thirteenth summers, respectively). Size composition of Arctic grayling was described with the incremental Relative Stock Density (RSD) indices of Gabelhouse (1984). The RSD categories are: "stock" (150 to 269 mm FL); "quality" (270 to 339 mm FL); "preferred" (340 to 449 mm FL); "memorable" (450 to 559 mm FL); and, "trophy" (> 559 mm FL). Tests of assumptions 2 and 3 for estimation of abundance indicated which data to use for estimating age and size compositions. First, the proportions of fish by age class or size category were estimated as:

$$\hat{p}_k = \frac{n_k}{n} \tag{3}$$

where: $\hat{p}_k$ = the proportion of age or size category k fish sampled; n_k = the number of age or size category k fish sampled; and, n = the number of fish sampled.

Variance of this proportion was estimated as the variance of a binomial. Next, the abundance of each age class or size category was estimated from the proportions and abundance in each stratum:

$$\hat{N}_k = \hat{p}_k \hat{N} \tag{4}$$

where: $\hat{N}_k$ = the abundance of age or size category k fish.

Variance of each abundance at age or size was estimated with the formula for the variance of the product of two independent variables (Goodman 1960):

$$\hat{V}\left[\hat{N}_k\right] = \hat{p}_k^2 \hat{V}\left[\hat{N}\right] + \hat{N}^2 \hat{V}\left[\hat{p}_k\right] - \hat{V}\left[\hat{N}\right] \hat{V}\left[\hat{p}_k\right]. \tag{5}$$

RESULTS

In 1996, 93 angler-days (513 angler hr) of effort captured 916 Arctic grayling ≥ 150 mm FL from 15 to 31 July (Appendix B1; individual catch rates per angler were not recorded). Fifty-four angler-days, 58% of the total, were attributable to 31 volunteers with the remaining effort due to nine department personnel. Seven fish died during sampling. Fifty-nine fish were either victims of mink predation or escaped the pens during the predation. The marking event occurred from 15 to 21 July with 442 fish ≥150 mm FL released with marks. The recapture event occurred from 23 to 31 July and captured 405 fish ≥ 150 mm FL with 54 fish being recaptures. Since the smallest recapture was 240 mm, the target population was truncated to fish ≥ 240 mm (Table 2). Tests for size selectivity on this population were not significant and size stratification was not necessary ($P \geq 0.21$; Table 2, Appendix C1). A Pearson chi-square test to compare proportions of recaptures among examined fish in stratum 1 (upstream of the campground) vs stratum 2 (downstream) was not significant and area stratification was not necessary ($\chi^2 = 1.15$, df = 1, $P=0.28$; Table 2). The Bailey estimate is 3,000 fish ≥ 240 mm (SE = 370; Table 2). For fish > 270 mm, the estimate is 2,750 (SE = 370).

Age and size compositions in 1996 were estimated for fish ≥ 240 mm from pooled events since there was no significant size bias in the experiment. Ages 5 and 6 fish comprised near equal proportions and together accounted for 48% of the 558 fish ≥ 240 mm that could be aged (p = 0.22 and 0.26, respectively, SE = 0.02 for both; Table 3). These age compositions were not significantly different from the composition found in the total sample (Appendix B4). Abundance of fish of age 5 and older was 2,490 fish (SE = 310; Table 2).

RSD estimates for 1996 were compromised due to the truncation of the experiment to fish ≥ 240 mm which excluded the majority of stock sized fish (150-269 mm FL; Table 4). Fish in the quality (270-339 mm) and preferred (340-449 mm) categories were near equally represented.

In 1997, 101 angler-days (601 angler hr) of effort captured 1,491 Arctic grayling ≥ 150 mm FL from 14 to 25 July (Appendix B2). Individual catch rates of 21 anglers ranged from 4.83 to 0.68 Arctic grayling per hour (Appendix B3). Fifty-nine man-days, 54% of the total, were expended by 16 volunteers with the remaining effort due to eight department personnel. Four fish were killed during the experiment. The marking event ran from 14 to 18 July with 666 fish ≥ 150 mm FL released with marks. The recapture event ran from 21 to 25 July and captured 825 fish ≥ 150 mm FL with 60 fish being recaptures. While the smallest recapture was 168 mm, there was no significant difference between recapture rates for small (150-239 mm), medium (240-269 mm), and large sized fish (≥ 270 mm) and the data was not truncated ($\chi^2 = 5.55$, df = 2, $P = 0.06$). Size selectivity was found in the mark event but not in the recapture event and size stratification was not necessary however, compositions were estimated only from the recapture event (event 1 vs event 2, $P < 0.01$ and event 1 vs recaptures $P = 0.94$; Table 2, Appendix C1). While capture probability (R/C ratio) between sections was significantly different ($\chi^2 = 23.24$, df = 2, $P < 0.01$, Table 2) due to differential movement of recaptures (Table 5), recapture rates (R/M ratio) were not ($\chi^2 = 0.80$, df = 1, $P = 0.37$, Table 2) and area stratification was not necessary. The Bailey estimate was 9,000 fish ≥ 150 mm (SE = 1,100 and 6,490 fish ≥ 270 mm (SE = 800; Table 2).

Age and size compositions in 1997 were estimated for fish ≥ 150 mm from the second event. Age 4 was the predominant age class in the sample comprising 0.27 (SE = 0.02) of the 717 fish in the sample (Table 6, Appendix B5). Ages 6 and 3 fish were the next most numerous. (0.19 and 0.15 respectively, SE = 0.01 for both). Abundance of fish of age 5 and older was 4,600 fish (SE = 590 fish; Table 2). Quality and preferred sized fish were near equal in 1997 RSD estimates (0.37 and 0,35, respectively, SE = 0.02; Table 4).

Table 2.-Summary of analyses of two event mark-recapture experiments of Arctic grayling in the Delta Clearwater River, July 1996 and 1997 (standard errors are in parentheses).

Category	1996	1997
Shortest recapture (mm FL)	240	168
Size selectivity tests:		
First event vs recaptured	$P = 0.21$	$P = 0.94$
First event vs second event	$P = 0.42$	$P < 0.01$
R/C test among locations	$P = 0.28$	$P < 0.01$
R/M test among locations	na	$P = 0.37$
Statistics:		
Number marked first event	424	666
Number examined second event	388	825
Number recaptured second event	54	60
Abundance (SE):		
≥ 150 mm FL	na	9,000 (1,100)
≥ 240 mm FL	3,000 (370)	7,420 (920)
≥ 270 mm FL	2,750 (340)	6,490 (800)
≥ age 5	2,490 (310)	4,600 (590)

[a] na = not applicable.

Table 3.-Estimates of age composition and abundance by age class with standard errors for Arctic grayling (≥240 mm FL), Delta Clearwater River, July 1996.

	Age Composition			Abundance		
Age Class	n	p	SE[p]	N	SE[N]	cv
3	45	0.08	0.01	242	46	19%
4	51	0.09	0.01	274	50	18%
5	124	0.22	0.02	666	98	15%
6	147	0.26	0.02	790	112	14%
7	87	0.16	0.02	468	74	16%
8	36	0.06	0.01	193	39	20%
9	40	0.07	0.01	215	42	20%
10	15	0.03	0.01	81	23	28%
11	8	0.01	0.01	43	16	37%
12	5	0.01	0.00	27	12	46%
Total	558	1.00	---	2,999	371	12%

Table 4.-Relative Stock Density (RSD) indices of Arctic grayling captured in the Delta Clearwater River, July 1996 and 1997.

Category	Length (mm FL)	n	RSD	SE[RSD	N	SE[N]
1996 (≥ 240 mm FL only):						
Stock	150 – 269	62	0.08	0.01	245	42
Quality	270 – 339	324	0.43	0.02	1,280	170
Preferred	340 – 449	371	0.49	0.02	1,470	190
Memorable	450 – 559	1	0.00	0.00	4	4
Trophy	≥560	0	0.00	0.00	---	---
Total		758	1.00	---	2,999	371
1996 (≥ 270 mm FL only):						
Stock	150 – 269	na	---	---	---	---
Quality	270 – 339	324	0.47	0.02	1,280	170
Preferred	340 – 449	371	0.53	0.02	1,470	190
Memorable	450 – 559	1	<0.01	<0.01	4	4
Trophy	≥560	0	---	---	0	---
Total			1.00		2,755	342
1997(≥ 270 mm FL only):						
Stock	150 – 269	na	---	---	---	---
Quality	270 – 339	302	0.51	0.02	3,300	430
Preferred	340 – 449	291	0.49	0.02	3,180	420
Memorable	450 – 559	1	<0.01	<0.01	11	11
Trophy	≥560	0	---	---	0	---
Total		825	1.00	---	6,493	806
1997 (≥150 mm FL):						
Stock	150 – 269	231	0.28	0.02	2,530	340
Quality	270 – 339	302	0.37	0.02	3,300	430
Preferred	340 – 449	291	0.35	0.02	3,180	420
Memorable	450 – 559	1	<0.01	<0.01	11	11
Trophy	≥560	0	---	---	0	---
Total		825	1.00	---	9,021	1,100

a na = not applicable.

Table 5.-Data summary for recapture movements in the 1997 mark-recapture experiment.

		Recapture Location		
Mark Location	Marks	Downstream	Upstream	R/M[a]
Downstream	375	30	0	0.08
Upstream	291	14	16	0.10
Examined without marks=		331	434	
R/C[b]=		0.12	0.04	

[a] R/M = recapture rate, number of recaptures divided by number of marked fish released in the first event.

[b] R/C = capture probability, number of recaptures divided by number of fish examined in second event.

Table 6.-Estimates of age composition and abundance by age class with standard errors for Arctic grayling (≥150 mm FL), Delta Clearwater River, July 1997.

	Age Composition			Abundance		
Age Class	n	p	SE[p]	$\hat{N}$	SE[$\hat{N}$]	cv
1	2	0.00	0.00	25	18	71%
2	46	0.06	0.01	579	108	19%
3	109	0.15	0.01	1,371	206	15%
4	195	0.27	0.02	2,453	335	14%
5	64	0.09	0.01	805	137	17%
6	139	0.19	0.01	1,748	251	14%
7	71	0.10	0.01	893	148	17%
8	48	0.07	0.01	604	112	18%
9	21	0.03	0.01	264	65	25%
10	12	0.02	0.00	151	47	31%
11	7	0.01	0.00	88	35	39%
12	1	0.00	0.00	13	13	100%
13	2	0.00	0.00	25	18	71%
Total	717	1.00	---	9,018	1,102	12%

DISCUSSION

The 1996 and 1997 Peterson mark-recapture experiments for DCR Arctic grayling did not have the biases that affected earlier attempts in 1988 and 1995. The duration and various gear types of the marking events in 1988 and 1995 introduced biases from size selectivity, growth, immigration and emigration; additionally anglers selected against tagged fish which introduced bias in the recapture event (W. P. Ridder, ADF&G, Delta unpublished data). In an early attempt at a mark-recapture experiment an electrofishing boat (1980 unpublished data) was used in the upper river in July but was thwarted by small sample sizes brought on by the tendency of repeated electrofishing to introduce gear shyness as well as forcing emigration out of the study area.

While the DCR Arctic grayling population and fishery have been the focus of 33 studies since 1953, abundance, recruitment, and exploitation have only recently been estimated. These parameter estimates are essential to the assessment of the population and the ability of management to provide a fishery that is sustainable and meets public desires. Past assessments relied almost solely on fishery performance and culminated in a management plan that stated the fishery was healthy and could sustain harvests of up to 3,000 fish annually (ADF&G 1993). catch-age modeling of the population from 1977 through 1990 and the data presented in this report suggest otherwise (Figure 3). These studies indicated that chronic overexploitation, averaging 34% between 1977 and 1990 and 27% in 1996, was the likely cause of steady decline in abundance of age 5+ fish from 12,800 fish in 1983, to 4,500 in 1990 and 2,494 in 1996 (Clark and Ridder 1994). In 1997, abundance of age 5+ fish dramatically increased to 4,603 due not only to an unexpectedly large recruitment of age 4 fish but also to greater numbers of fish age 6 and older. Recruitment to the DCR is entirely from other streams and has been thought to be essentially complete by age 5. However, the mechanism of this recruitment is unknown and may be influenced by environmental factors. In 1997, record low discharges occurred in run-off rivers of the Tanana drainage due to low precipitation. In contrast, the spring-fed DCR exhibited its normal level of discharge. The large difference in estimated abundance of fish $\geq$ 270 mm FL between 1996 and 1997 may be due in part to the attractive refuge of the DCR in 1997 to Arctic grayling seeking cool temperatures and adequate flows. The no harvest regulation imposed in June 1997 may also have influenced estimated abundance of Arctic grayling in 1997. Estimates of abundance of the DCR population should continue to assess the need of the no harvest regulation, the population response, and to gain new insights into the complex behavior and dynamics of the population and Arctic grayling biology in general.

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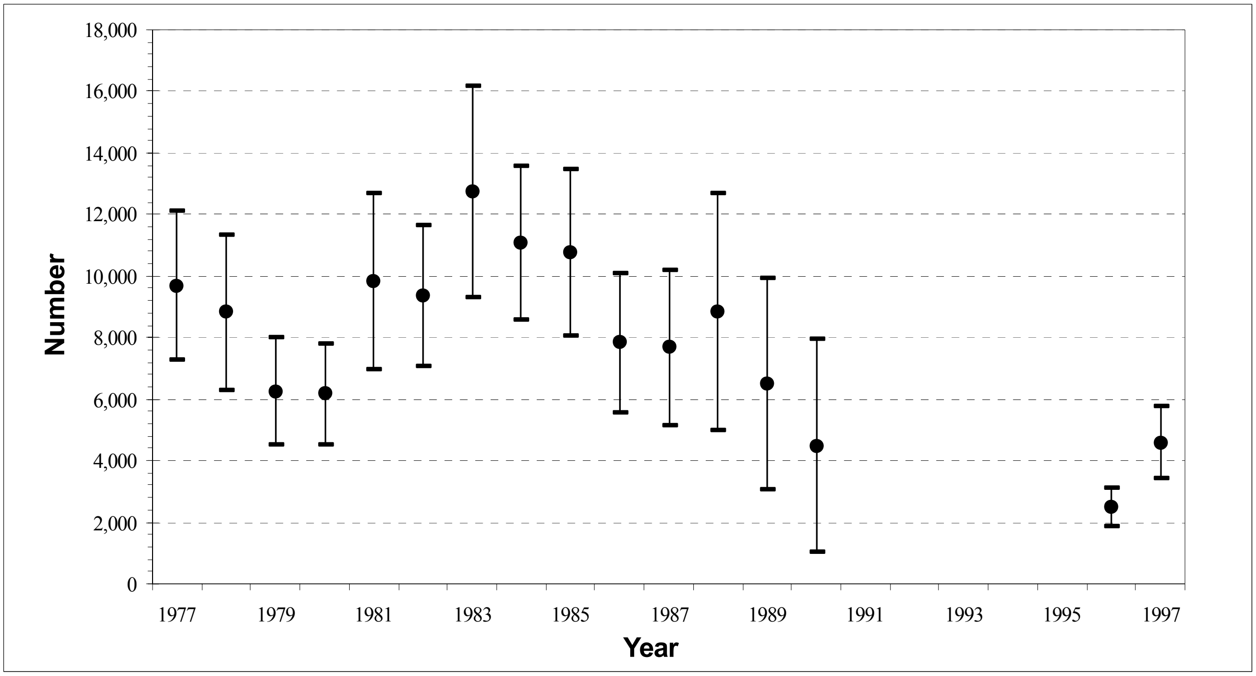

Figure 3.-Abundance of Arctic grayling of age 5 and older with 95% confidence intervals from catch-age estimates (1977-1990; from Clark and Ridder 1994) and from mark-recapture experiments (1996-1997), Delta Clearwater River.

LITERATURE CITED

ADF&G. 1993. Recreational fishery management plan for Arctic grayling in the Delta Clearwater River. Alaska Department of Fish and Game, Sport Fish Division, Fairbanks.

Bailey, N. T. J. 1951. On estimating the size of mobile populations from capture-recapture data. Biometrika 38: 293-306.

Bailey, N. T. J. 1952. Improvements in the interpretation of recapture data. Journal of Animal Ecology 21: 120-127.

Brown, C. J. D. 1943. Age and growth of Montana grayling. The Journal of Wildlife Management 7:353-364.

Chapman, D. G. 1951. Some properties of the hypergeometric distribution with applications to zoological censuses. University of California Publications in Statistics 1:131-160.

Clark, R. A. 1992. Age and size at maturity of Arctic grayling in selected waters of the Tanana drainage. Alaska Department of Fish and Game, Fishery Manuscript No. 92-5, Anchorage.

Clark, R. A. And W. P. Ridder. 1994. An age-structured stock analysis of Arctic grayling in the Delta Clearwater River, 1977 to 1990. Alaska Dept. of Fish and Game, Fishery Manuscript No. 94-4, Anchorage.

Gabelhouse, D. W. 1984. A length-categorization system to assess fish stocks. North American Journal of Fisheries Management 4: 273-285.

Goodman, L. A. 1960. On the exact variance of products. Journal of the American Statistical Association 66: 708-713.

Howe, A. L., G. Fidler, and M. J. Mills. 1995. Harvest, catch, and participation in Alaska sport fisheries during 1994. Alaska Department of Fish and Game, Fishery Data Series No. 95-24, Anchorage.

Howe, A. L., G. Fidler, A. E. Bingham, and M. J. Mills. 1996. Harvest, catch, and participation in Alaska sport fisheries during 1995. Alaska Department of Fish and Game, Fishery Data Series No. 96-32, Anchorage.

Howe, A. L., G. Fidler, C. Olnes, A. E. Bingham, and M. J. Mills. 1997. Harvest, catch, and participation in Alaska sport fisheries during 1996. Alaska Department of Fish and Game, Fishery Data Series No. 97-29, Anchorage.

Howe, A. L., G. Fidler, C. Olnes, A. E. Bingham, and M. J. Mills. 1998. Harvest, catch, and participation in Alaska sport fisheries during 1997. Alaska Department of Fish and Game, Fishery Data Series No. 98-25, Anchorage.

Kruse, T. E. 1959. Grayling of Grebe Lake, Yellowstone National Park, Wyoming. U.S. Fish and Wildlife Service Fishery Bulletin 59:307-351.

Mills, M. J. 1979. Alaska statewide sport fish harvest studies (1977). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1978-1979, Project F-9-11, 20 (SW-I-A).

Mills, M. J. 1980. Alaska statewide sport fish harvest studies (1978). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1979-1980, Project F-9-12, 21 (SW-I-A).

Mills, M. J. 1981a. Alaska statewide sport fish harvest studies (1979). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1980-1981, Project F-9-13, 22 (SW-I-A).

Mills, M. J. 1981b. Alaska statewide sport fish harvest studies (1980). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1980-1981, Project F-9-13, 22 (SW-I-A).

Mills, M. J. 1982. Alaska statewide sport fish harvest studies (1981). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1981-1982, Project F-9-14, 23 (SW-I-A).

Mills, M. J. 1983. Alaska statewide sport fish harvest studies (1982). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1982-1983, Project F-9-15, 24 (SW-I-A).

Mills, M. J. 1984. Alaska statewide sport fish harvest studies (1983). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1983-1984, Project F-9-16, 25 (SW-I-A).

Mills, M. J. 1985. Alaska statewide sport fish harvest studies (1984). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1984-1985, Project F-9-17, 26 (SW-I-A).

Mills, M. J. 1986. Alaska statewide sport fish harvest studies (1985). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1985-1986, Project F-10-1, 27 (RT-2).

Mills, M. J. 1987. Alaska statewide sport fisheries harvest report (1986). Alaska Department of Fish and Game, Fishery Data Series No. 2, Juneau.

Mills, M. J. 1988. Alaska statewide sport fisheries harvest report (1987). Alaska Department of Fish and Game, Fishery Data Series No. 52, Juneau.

Mills, M. J. 1989. Alaska statewide sport fisheries harvest report (1988). Alaska Department of Fish and Game, Fishery Data Series No. 122, Juneau.

Mills, M. J. 1990. Harvest and participation in Alaska sport fisheries during 1989. Alaska Department of Fish and Game, Fishery Data Series No. 90-44, Anchorage.

Mills, M. J. 1991. Harvest, catch, and participation in Alaska sport fisheries during 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-58, Anchorage.

Mills, M. J. 1992. Harvest, catch, and participation in Alaska sport fisheries during 1991. Alaska Department of Fish and Game, Fishery Data Series No. 92-40, Anchorage.

Mills, M. J. 1993. Harvest, catch, and participation in Alaska sport fisheries during 1992. Alaska Department of Fish and Game, Fishery Data Series No. 93-42, Anchorage.

Mills, M. J. 1994. Harvest, catch, and participation in Alaska sport fisheries during 1993. Alaska Department of Fish and Game, Fishery Data Series No. 94-28, Anchorage.

Peckham, R. D and W. P. Ridder. 1979. A study of a typical spring-fed stream of interior Alaska. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report, 1978-1979. Project F-9-11, 20 (G-III-G): 25-64.

Reed, R. J. 1961. Investigations of the Tanana River grayling fisheries: creel census - Chatanika and Delta Clearwater Rivers. Alaska Department of Fish and Game. Federal Aid in Sport Fish Restoration, Annual Report of Progress, 1960-1961, Project F-5-R-2, Job 3-C.

Ridder, W. P. 1985. Life history and population dynamics of exploited grayling stocks - Delta and Richardson Clearwater Rivers. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1984-1985, Project F-9-17, 26(G-III-G):1-58.

Ridder, W. P. 1991. Summary of recaptures of Arctic grayling tagged in the middle Tanana River drainage, 1977 through 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-34, Anchorage.

Ridder, W. P. *In prep.* Stock status and radio telemetry of Arctic grayling in the Chena River. Alaska Department of Fish and Game, Fishery Data Series, Anchorage.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters, second edition. Charles Griffin and Co., Ltd. London, U.K. 654 pp.

Tack, S. L. 1973. Distribution, abundance, and natural history of the Arctic grayling in the Tanana River drainage. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1972-1973, Project F-9-5, 14(R-1).

Tack, S. L. 1980. Migrations and distribution of Arctic grayling, *Thymallus arcticus* (Pallas), in interior and Arctic Alaska. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1979-1980. Project F-9-12, 21(R-I).

APPENDIX A
DATA FILE LISTING

Appendix A1.-Data files[a] used to estimate parameters of the Arctic grayling population in the Delta Clearwater River, 1996 and 1997.

Data file	Description
U006ALA5	Population data from 15-31 July 1996.
U0060LAA	Population data from 14-25 July 1997.

[a] Data files are archived at and are available from the Alaska Department of Fish and Game, Sport Fish Division, Research and Technical Services, 333 Raspberry Road, Anchorage, Alaska 99518-1599.

APPENDIX B
Sampled Age and Size Compositions

Appendix B1.-Summary of effort, catch, and catch per unit effort (number of Arctic grayling caught per angler-hour) for the mark-recapture experiment in the Delta Clearwater River 1996.

Mark Event, July 15 – 21					
Section	River mi	Angler-days	Angler-hrs	Catch	CPUE
Upstream	14 - 12	6	39	72	1.85
	12 - 10	6	28	26	0.93
	10 - 8	8	32	52	1.63
	subtotal:	20	99	150	1.52
Downstream	8 - 7	6	34	60	1.76
	7 - 5	16	61	98	1.62
	5 - 3	9	47	128	2.72
	3 - 1	7	30	35	1.17
	subtotal:	31	172	321	1.87
Mark Total:		51	271	471	1.74

Catch Event, July 23 -					
Section	River mi	Angler-days	Angler-hrs	Catch	CPUE
Upstream	14 - 12	4	25	48	1.94
	12 - 10	6	30	59	1.96
	10 - 8	7	44	44	1.01
	subtotal:	17	98	151	1.53
Downstream	8 - 7	3	15	30	2.07
	7 - 5	13	55	100	1.81
	5 - 3	9	50	120	2.40
	3 - 1	5	25	44	1.80
	subtotal:	25	144	294	2.04
Catch Total:		42	243	445	1.83
Total for Experiment:		93	513	916	1.78

Appendix B2.-Summary of effort, catch, and catch per unit effort (number of Arctic grayling caught per angler-hour) for the mark-recapture experiment in the Delta Clearwater River 1997.

Mark Event, July 14 - 18:					
Section	River mi	Angler-days	Angler-hrs	Catch	CPUE
Upstream	14 - 12	5	31	128	4.10
	12 - 10	8	79	68	0.86
	10 - 8	8	49	95	1.96
	subtotal:	21	159	291	1.83
Downstream	8 - 6	9	51	88	1.73
	6 - 4	8	36	130	3.61
	4 - 1	16	69	157	2.27
	subtotal:	33	156	375	2.40
Mark Total:		54	315	666	2.11

Catch Event, July 21 - 25					
Section	River mi	Angler-days	Angler-hrs	Catch	CPUE
Upstream	14 - 12	8	39	106	2.72
	12 - 10	9	38	123	3.24
	10 - 8	9	55	221	4.02
	subtotal:	26	132	450	3.41
Downstream	8 - 6	12	59	101	1.73
	6 - 4	5	31	86	2.77
	4 - 1	13	65	188	2.91
	subtotal:	30	154	375	2.44
Catch Total:		56	286	825	2.88
Total for Experiment:		110	601	1,491	2.48

Appendix B3.-Individual effort, catch, and catch per unit effort (number of Arctic grayling caught per angler-hour) during the mark-recapture experiment in the Delta Clearwater River 1997.

Angler	Hours	Catch	CPUE
1	69	332	4.83
2	34	144	4.30
3	28	110	3.96
4	13	51	3.92
5	46	160	3.46
6	17	52	3.06
7	19	55	2.97
8	12	35	2.92
9	56	126	2.25
10	5	11	2.20
11	13	28	2.15
12	6	10	1.67
13	40	63	1.58
14	55	86	1.58
15	27	37	1.37
16	6	7	1.17
17	27	28	1.04
18	55	46	0.84
19	6	5	0.83
20	46	36	0.78
21	24	16	0.68
Total	601	1,438	2.39
Average	29	68	2.27
Median	27	46	2.15

Appendix B4.-Estimates of age composition and mean length for all Arctic grayling captured by hook and line in the Delta Clearwater River, 19-31 July 1996.

	Age Composition			Length (mm FL)			
Age Class	n	p	SE[p]	mean	std	min	max
1	1	0.00	0.00	134	---	134	134
2	5	0.01	0.00	191	16	174	210
3	72	0.12	0.01	247	20	208	300
4	51	0.09	0.01	283	20	243	323
5	124	0.21	0.02	313	23	246	382
6	147	0.25	0.02	339	23	291	402
7	87	0.15	0.01	366	23	310	410
8	36	0.06	0.01	382	23	326	426
9	40	0.07	0.01	397	18	354	428
10	15	0.03	0.01	401	19	373	438
11	8	0.01	0.00	421	14	399	439
12	5	0.01	0.00	426	28	391	464
Total	591	1.00	---	334	52	134	464

Appendix B5.-Estimates of age composition and mean length for all Arctic grayling captured by hook and line in the Delta Clearwater River, 21-25 July 1997.

	Age Composition			Length (mm FL)			
Age Class	n	p	SE[p]	mean	std	min	max
1	2	0.00	0.00	146	6	142	150
2	46	0.06	0.01	184	10	158	204
3	109	0.15	0.01	230	18	190	293
4	195	0.27	0.02	279	22	224	353
5	64	0.09	0.01	317	27	259	372
6	139	0.19	0.01	343	22	290	405
7	71	0.10	0.01	358	22	310	405
8	48	0.07	0.01	373	26	312	419
9	21	0.03	0.01	393	24	348	443
10	12	0.02	0.00	399	25	354	445
11	7	0.01	0.00	395	46	304	462
12	1	0.00	0.00	434	---	434	434
13	2	0.00	0.00	431	25	413	449
Totals	717	1.00	---	306	63	142	462

Appendix B6.-Relative Stock Density (RSD) indices of all Arctic grayling (≥150 mm FL) captured during mark-recapture experiments in the Delta Clearwater River, July 1996 and 1997.

1996:

Category	Length (mm FL)	n	RSD	SE[RSD]
Stock	150 - 269	96	0.12	0.01
Quality	270 - 339	328	0.41	0.02
Preferred	340 - 449	372	0.47	0.02
Memorable	450 - 559	1	<0.01	0.00
Trophy	≥560	0	---	---
Total		797	1.00	---

1997:

Category	Length (mm FL)	n	RSD	SE[RSD]
Stock	150 - 269	347	0.24	0.01
Quality	270 - 339	557	0.39	0.01
Preferred	340 - 449	528	0.37	0.01
Memorable	450 - 559	1	0.00	0.00
Trophy	≥560	0		
Total		1,433		

Appendix B7.-Estimates of age composition and abundance at age for Arctic grayling (≥270 mm FL), Delta Clearwater River, 1996-1997.

1996	Age	n	p	SE	N	SE[N]	cv
	3	11	0.02	0.01	60	19	32%
	4	37	0.07	0.01	201	40	20%
	5	121	0.24	0.02	657	97	15%
	6	147	0.29	0.02	799	114	14%
	7	87	0.17	0.02	473	74	16%
	8	36	0.07	0.01	196	40	20%
	9	40	0.08	0.01	217	42	20%
	10	15	0.03	0.01	81	23	28%
	11	8	0.02	0.01	43	16	37%
	12	5	0.01	0.00	27	12	46%
	Total	507	1.00	---	2,755	342	12%

1997	Age	n	p	SE	N	SE[N]	cv
	3	5	0.01	0.00	64	29	46%
	4	136	0.27	0.02	1,742	251	14%
	5	66	0.13	0.01	845	142	17%
	6	143	0.28	0.02	1,831	261	14%
	7	73	0.14	0.02	935	154	16%
	8	43	0.08	0.01	551	105	19%
	9	21	0.04	0.01	269	66	25%
	10	11	0.02	0.01	141	45	32%
	11	6	0.01	0.00	77	32	42%
	12	1	0.00	0.00	13	13	100%
	13	2	0.00	0.00	26	18	71%
	Total	507	1.00		6,493	806	12%

APPENDIX C
STATISTICAL METHODOLOGY

Appendix C1.-Methodology to compensate for bias due to gear selectivity by means of statistical inference.

Case	Result of First K-S Test	Result of second K-S test[b]	Inferred Cause
I[c]	Fail to reject H_o	Fail to reject H_o	There is no size-selectivity during either sampling event.
II[d]	Fail to reject H_o	Reject H_o	There is no size-selectivity during the second sampling event, but there is during the first sampling event.
III[e]	Reject H_o	Fail to reject H_o	There is size-selectivity during both sampling events.
IV[f]	Reject H_o	Reject H_o	There is size-selectivity during the second sampling event; the status of size-selectivity during the first event is unknown.

[a] The first K-S (Kolmogorov-Smirnov) test is on the lengths of fish marked during the first event versus the lengths of fish recaptured during the second event. H_o for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish recaptured during the second event.

[b] The second K-S test is on the lengths of fish marked during the first event versus the lengths of fish captured during the second event. H_o for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish sampled during the second event.

[c] Case I: Calculate one unstratified abundance estimate, and pool lengths and ages from both sampling events for size and age composition estimates.

[d] Case II: Calculate one unstratified abundance estimate, and only use lengths and ages from the second sampling event to estimate size and age composition.

[e] Case III: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Pool lengths and ages from both sampling events and adjust composition estimates for differential capture probabilities.

[f] Case IV: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Also calculate a single abundance estimate without stratification.

Case IVa: If stratified and unstratified estimates are dissimilar, discard unstratified estimate and use lengths and ages from second event and adjust these estimates for differential capture probabilities.

Case IVb: If stratified and unstratified estimates are similar, discard estimate with largest variance. Use lengths and ages from first sampling event to directly estimate size and age compositions.

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